LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

BRITISH MUSEUM (NATURAL HISTORY)

THE
JOHN MURRAY EXPEDITION
1933–34

SCIENTIFIC REPORTS

VOLUME V, No. 5

THE ASTACURA AND PALINURA

BY

M. RAMADAN, PH.D.(CANTAB.)

WITH TWO APPENDICES AND TWELVE TEXT-FIGURES

LONDON:
PRINTED BY ORDER OF THE TRUSTEES OF THE BRITISH MUSEUM
SOLD BY
B. QUARITCH, LTD., 11 GRAFTON STREET, NEW BOND STREET, LONDON, W.1; DULAU & CO., LTD., 29 DOVER STREET, LONDON, W.1; OXFORD UNIVERSITY PRESS, WARWICK SQUARE, LONDON, E.C.4; H.M. STATIONERY OFFICE, LONDON, S.W.1
AND AT
THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD, LONDON, S.W.7
1938
[*All rights reserved*]
Price Two Shillings and Sixpence
[*Issued 26th February, 1938*]

DESIGNED AND
PRINTED
BY

AT
BARTHOLOMEW PRESS
DORKING

Made and printed in Great Britain

LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

THE ASTACURA AND PALINURA

BY

M. RAMADAN, PH.D.(CANTAB.)

WITH TWO APPENDICES AND TWELVE TEXT-FIGURES.

THE John Murray Collection of Astacura and Palinura is a small one, comprising only ten species, of which I have described one as new, belonging to the following Families :

PALINURA.
- ERYONIDEA.
  - Family ERYONIDÆ.
    - *Polycheles andamanensis* Alcock.
    - *P. typhlops* Heller.
- SCYLLARIDEA.
  - Family SCYLLARIDÆ.
    - *Scyllarus arctus* var. *paradoxus* Miers.
    - *S. orientalis* (Spence Bate).
    - *Thenus orientalis* (Rumph.).
    - *Ibacus incisus* (Peron).
  - Family PALINURIDÆ.
    - *Puerulus sewelli* sp. nov.
    - ? *P. carinatus* Borradaile.

ASTACURA.
- NEPHROPSIDEA.
  - Family NEPHROPSIDÆ.
    - *Nephropsis stewarti* Wood-Mason.
    - *N. suhmi* Spence Bate.

Family ERYONIDÆ.

Genus *Polycheles* Heller.

Polycheles, Spence Bate, 1888, p. 143 ; Faxon, 1895, p. 117 ; Alcock, 1901, p. 166 ; Stebbing, 1902, p. 34 ; Kemp and Sewell, 1912, p. 23 ; de Man, 1916, p. 21 ; Bouvier, 1917, p. 34 ; Balss, 1925, p. 200.
Pentacheles, Spence Bate, 1888, p. 143 ; Alcock, 1901, p. 171.
Stereomastis, Spence Bate, 1888, p. 154 ; de Man, 1916, p. 7.

Polycheles andamanensis Alcock.

Polycheles andamanensis, Alcock, 1901, p. 169 ; Illust. Zool. Investigator, Crust., pt. iii, 1895, pl. x, fig. 3.

Occurrence.—Sta. 59, South Arabian coast, depth 1948 m. ; 1 female.

Sta. 62, Northern area of Arabian Sea, depth 1893 m. ; 1 male.

The male specimen measures 45 mm. in length and the female 50 mm.

Distribution.—Off the Travancore coast of India, 1925 m. (Alcock), South Arabian coast and northern part of Arabian Sea.

Polycheles typhlops Heller.

Polycheles typhlops, Kemp and Sewell, 1912, p. 24 ; Selbie, 1914, p. 12, pl. i, figs. 1–13 ; de Man, 1916, p. 24 ; Stephenson, 1923, p. 67 ; Balss, 1925, p. 201, pl. ii ; Calman, 1925, p. 18.
Polycheles agassizii, Faxon, 1896, p. 155.
Pentacheles hextii, Alcock, 1901, p. 172 ; Illust. Zool. Investigator, Crust., pt. iii, 1895, pl. x, fig. 2.

Occurrence.—Sta. 34, Gulf of Aden, depth 1022 m. ; 10 males, 1 female.

Sta. 35, Gulf of Aden, depth 457–549 m. ; 1 male.

Sta. 115, Zanzibar area, depth 640–658 m. ; 3 males, 5 females.

Sta. 145, Maldive area, depth 494 m. ; 2 males.

Sta. 193, Gulf of Aden, depth 1061–1080 m. ; 3 males.

Two large females from Sta. 115 measure 157 mm. and 143 mm. in total length respectively, and are thus larger than any other specimen hitherto recorded from other parts of the world. The latter specimen (143 mm.) is ovigerous and has two spermatophores firmly cemented to the sternal surface between the coxæ of the 4th and 5th legs, while the former (157 mm.) bears three (possibly four) spermatophores in the same position. In the male specimen from Sta. 35 (60 mm.) a spermatophore was found projecting from the left genital orifice to a distance of about 8 mm.

Distribution.—Mediterranean Sea, Atlantic Ocean (West Indies, West of Ireland, Bay of Biscay, Portuguese coast and Cape Verde Islands), Indian Ocean (Andaman Sea, Arabian Sea and South African coast off Natal).

Vertical Distribution.—The species has been taken in the Mediterranean at depths of only 100 m. and 215 m. ; but it is usually caught at much greater depths down to 2050 m.

Family Nephropsidæ.

Genus *Nephropsis* Wood-Mason.

Nephropsis, Alcock, 1901, p. 157 ; de Man, 1916, p. 110 ; Bouvier, 1917, p. 19.

Nephropsis stewartii Wood-Mason. (Text-fig. 1.)

Nephropsis stewartii, Alcock, 1901, p. 159 ; Illust. Zool. Investigator, Crust., pt. iv, 1896, pl. xxvii, fig. 1 ; de Man 1916, p. 112 ; pl. iii, fig. 17 ; Balss, 1925, p. 209 ; Calman, 1925, p. 21.

Occurrence.—Sta. 34, Gulf of Aden, depth 1022 m. ; 1 male.

Sta. 193, Gulf of Aden, depth 1061–1080 m. ; 1 female.

The male specimen measures 108 mm. and the female 135 mm. from the tip of the rostrum to the end of the telson.

DISTRIBUTION.—East Indian Archipelago (560 m.), Andaman Sea (350–750 m.), Bay of Bengal (500 m.), Arabian Sea (660–850 m.) and African coast, off Natal (425 m.).

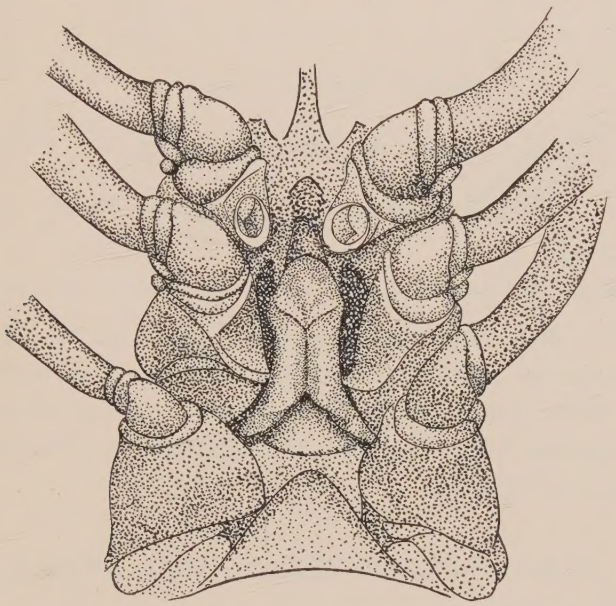
Nephropsis suhmi Spence Bate.

Nephropsis suhmi, Spence Bate, 1888, p. 181, pl. xxiii, fig. 3, pl. xxxiv, fig. 2; Alcock, 1901, p. 163; de Man, 1916, p. 114.

OCCURRENCE.—Sta. 33, Gulf of Aden, depth 1295 m.; 1 female.

Sta. 62, northern area of Arabian Sea, depth 1893 m.; 4 males, 7 females, 1 hermaphrodite.

Sta. 158, Maldive area, depth 786–1170 m.; 1 female.



TEXT-FIG. 1.—*Nephropsis stewarti*. Spermatheca.

The figure of this species given by Spence Bate (1888, pl. xxiii, fig. 3) is not correct; it shows the rostrum to be as long as the carapace and the cervical groove is figured much anterior to where it should be. The actual specimen in the "Challenger" collection in the British Museum (Nat. Hist.) from which the figure is taken has been compared with the figure, and it was found that the rostrum is more than half, but is not as long as, the carapace and the cervical groove is situated posterior to the middle of the carapace.

The rostrum normally carries two spines on either side, but in two females from Sta. 62 it carries three spines on the right side and two on the left; in one male from Sta. 33 it bears no spines on either side. This last specimen also bears no spines on the anterior edge of the 2nd–5th abdominal terga, where usually in this species one or two spines are present.

A specimen from Sta. 62 is peculiar in possessing certain male characters united with those of the female; of the female characters it has a well-developed spermatheca between the 4th pair of legs and an appendix interna on the 2nd pleopod; of the male characters it possesses a petasma, though a reduced one; coxal hooks on the 3rd legs similar to those

found in the male, and the genital apertures are situated on the last pair of legs. A similar case of hermaphroditism was recorded by Selbie (1914, p. 52) in a specimen of *Nephropsis atlantica*.

The following are the measurements in mm. of the total length and carapace length of the specimens :

From Sta. 33 : 34 (16).
,, Sta. 62 : 62 (30) ; 57 (27) ; 46 (23) ; 37 (19) ; 30 (15) ; 30 (15).
82 (39) ; 52 (25) ; 41 (21) ; 37 (19).
78 (38).
,, Sta. 158 : 24 (12).

Distribution.—East Indian Archipelago, 2029 m. (de Man) ; off Dobba, Arrou Islands, 1474 m. (Spence Bate) and Arabian Sea, 1596–1748 m.

Family Scyllaridæ Gray.

Genus *Scyllarus* Fabricius.

Scyllarus arctus, var. *paradoxus* Miers.

Scyllarus paradoxus, Miers, 1881, p. 364.
Scyllarus arctus var. *paradoxus*, Bouvier, 1917, p. 108, pl. x, fig. 3, and pl. xi, figs. 3, 4 ; Balss, 1925, p. 204.

Occurrence.—Sta. 45, South Arabian coast, depth 38 m. ; 3 males.

The three specimens are small and measure about 22 mm. in total length.

Distribution.—Goree Bay, Senegambia (Miers) ; mouth of the Congo River (Balss). The present record increases the range from the west to the east coast of Africa and from the Atlantic to the Indian Ocean.

Scyllarus orientalis (Spence Bate). (Text-fig. 2.)

Arctus orientalis, Spence Bate, 1888, p. 68, pl. ix, fig. 4 ; Alcock, 1901, p. 181.
Scyllarus orientalis, de Man, 1916, p. 73.

Occurrence.—Sta. 16, Gulf of Aden, depth 186 m. ; 1 female.

Sta. 106, Zanzibar area, depth 183–194 m. ; 8 males, 1 female.

Sta. 194, Gulf of Aden, depth 220 m. ; 58 males, 38 females.

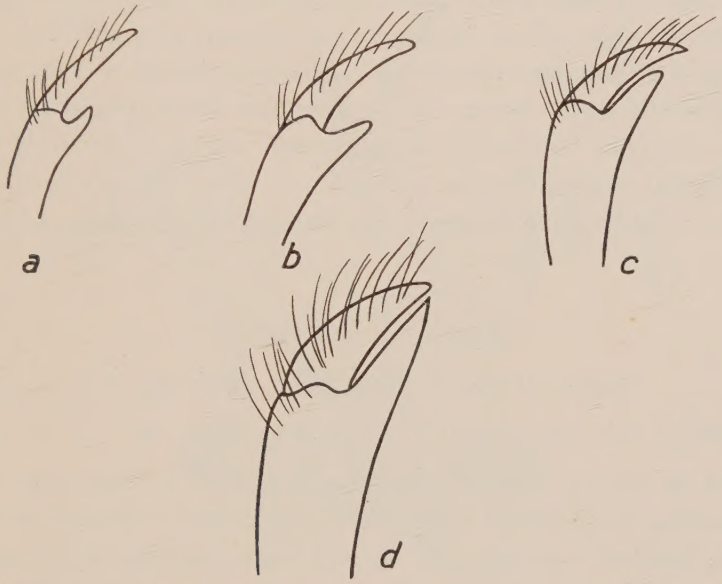
Descriptive Notes.—The carapace, measured in the mid-dorsal line, is approximately as long as the abdomen without the telson, and its length is about equal to its breadth (measured at the antero-lateral angles). In most specimens the 3rd joint of the antennular peduncle reaches by more than three-quarters of its length beyond the antenna ; the 2nd leg reaches by half the dactylus beyond the 1st ; and the 3rd leg as far as the 2nd. The 4th leg, which is the longest in both sexes, reaches by half the dactylus beyond the 3rd, and by a dactylus and a third of the propodus beyond the 5th leg. In the female the 5th pair is perfectly chelate in large specimens, but not in small examples, in which the projecting part of the propodus is still small ; Text-fig. 2 shows the gradual formation of a perfect chela.

The specimens from Sta. 106 differ from the others in that the arborescent markings on the abdominal terga and the sculpturing of the carapace are less distinct.

Of the females from Sta. 194, 21 specimens are ovigerous.

The following are the measurements in mm. of a few specimens of graded sizes; the legs were measured from the proximal end of the basis to the tip of the dactylus.

Sex.	Carapace length.	Carapace breadth.	Abdomen breadth.	Telson.	1st leg.	2nd leg.	3rd leg.	4th leg.	5th leg.
♂	34	33	35	15	27	33	39	48	47
	30	30	31	14	24	31	36	43	42
	27	28	27	13	22	28	33	40	39
	24	25	25	11	17	23	26	33	31
	22	22	21	10	16	20	23	27	26
♀	33	35	33	16	26	30	36	44	39
	31	32	31	15	25	30	36	42	37
	27	29	27	13	21	26	29	36	31
	21	23	22	11	17	20	24	28	23
	18	19	19	9	14	17	19	21	19
	15	16	16	7	12	15	16	19	17



TEXT-FIG. 2.—*Scyllarus orientalis*. Terminal joints of the 5th pair of thoracic legs, × 12, of four female specimens. (*a*) Carapace = 17 mm. (*b*) Carapace = 20 mm. (*c*) Carapace = 24 mm. (*d*) Carapace = 34 mm.

DISTRIBUTION.—Philippine Islands, East Indian Archipelago, Bay of Bengal and Arabian Sea (Arabian and African coasts).

Genus *Thenus* Leach.

Thenus, Stebbing, 1893, p. 193; Ortmann, 1901, p. 1138; de Man, 1916, p. 66.

Thenus orientalis (Rumph.).

Thenus orientalis, Milne-Edwards, 1837, p. 286; Ortmann, 1892, p. 46; Henderson, 1893, p. 433; Nobili, 1906, p. 88; Boone, 1935, p. 58, pls. xiv, xv.

OCCURRENCE.—Sta. 37, Gulf of Aden, depth 18–22 m.; 1 male.

DISTRIBUTION.—East Indian Archipelago, Indian Ocean, Persian Gulf and Red Sea.

Genus *Ibacus* Leach.

Ibacus, Stebbing, 1893, p. 193 ; Ortmann, 1901, p. 1138 ; de Man, 1916, p. 65 ; Bouvier, 1917, p. 103.

Ibacus incisus (Peron).

Ibacus incisus, Stebbing, 1893, p. 194, fig. 16.
Ibacus peronii, Desmarest, 1825, p. 183, pl. xxxi ; Leach, 1815, p. 152, pl. cxix ; Haswell, 1879, p. 168 ; de Man, 1916, p. 65.
? *Ibacus verdi*, Stebbing, 1910, p. 373.

Occurrence.—Sta. 106, Zanzibar area, depth 183–194 m. ; 1 female.

Descriptive Notes.—The specimen measures about 187 mm. from the anterior edge of the carapace between the eyes to the end of the telson.

This species resembles *Ibacus verdi* Spence Bate, but differs from it in the possession of only seven teeth on the lateral edge of the carapace behind the transverse incision, instead of twenty-two in *Ibacus verdi* Spence Bate ; again, the lateral edges of the carapace form, with the lateral edges of the abdomen, an almost straight line, which thus gives to the whole animal a triangular appearance. Stebbing (1910, p. 373) records from South African waters under the name *Ibacus verdi* a specimen which possesses seven teeth on the lateral edge of the carapace behind the deep incision, and it is probable that this example really belongs to *Ibacus incisus* (Peron) and not to *I. verdi* Spence Bate.

Distribution.—Southern seas—Sydney, Valparaiso (de Man) and (?) South Africa (Stebbing).

Family Palinuridæ.

Genus *Puerulus* Ortmann. (Text-fig. 3.)

Puerulus, Calman, 1909, p. 441 ; Gruvel, 1912, p. 6 ; de Man, 1916, p. 35.

The epistome of species of this genus is described by previous authors as being grooved in the middle longitudinal line ; the part which is referred to by these authors as the epistome is, however, not actually the epistome, but the two basal segments of the antennal peduncle, which are fused together, and the groove referred to above represents the line of their fusion. It is true that the epistome is fused with the basal segment of the antennal peduncle, but this fusion is not so complete as to mask the boundaries of both the epistome proper and the basal segment of the peduncle. The proximal edges of the basal segment of the antennal peduncle are very distinct and are clearly marked by the openings of the antennal glands. The epistome proper is not grooved (Text-fig. 3).

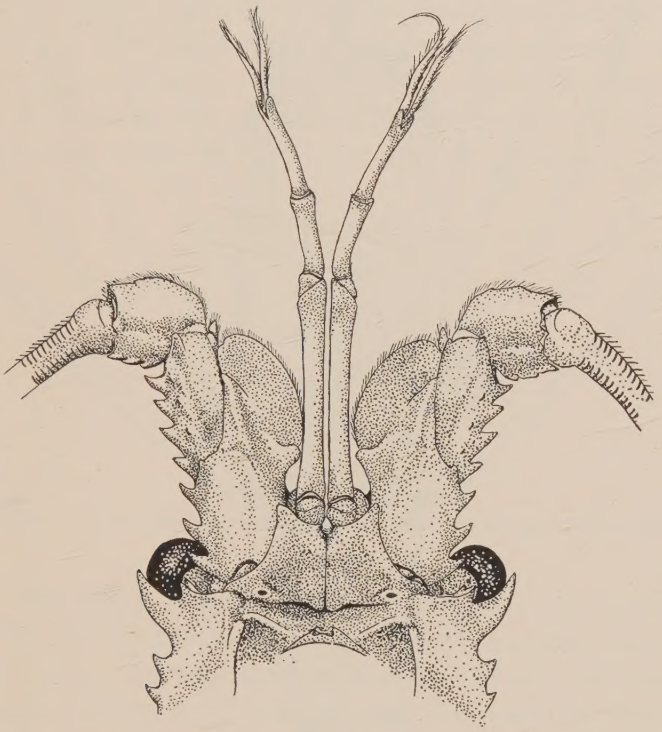
This genus is now represented by three species, namely, *Puerulus angulatus* (Spence Bate = *Puerulus angulatus* de Man), *Puerulus carinatus* Borradaile, and *Puerulus sewelli* sp. nov. (= *Panulirus angulatus* Alcock).

Puerulus sewelli sp. nov. (Text-figs, 3, 4 and 5.)

Panulirus angulatus, Alcock, 1901, p. 185.
Puerulus angulatus (part), Calman, 1909, p. 442.
nec *Puerulus angulatus*, de Man, 1916, p. 36 ; Spence Bate, 1888, p. 81, pl. xi, figs. 2–4.

Occurrence.—Sta. 24, Gulf of Aden, depth 73–200 m. ; 5 males, 8 females.
Sta. 194, Gulf of Aden, depth 220 m. ; 68 males, 5 females.

Descriptive Notes.—*Panulirus angulatus* Alcock and *Puerulus angulatus* (Spence Bate) have hitherto been considered synonymous ; but the detailed description of *Puerulus angulatus* (Spence Bate) given by de Man (1916, p. 36) is so different from that given by Alcock (1901) of specimens taken by the " Investigator " in Indian waters that he referred to this species, that the specific identity of de Man's and Alcock's examples seemed to be very doubtful. De Man himself pointed out many differences between his specimens and Alcock's description and, commenting on the measurements given by Alcock for one of the examples, he writes, " It is therefore remarkable that in all the specimens taken by the ' Siboga ' the abdomen appears almost twice as long as the carapace ". From a careful examination of the type-specimen of *Puerulus angulatus* (Spence Bate) in the British Museum and of two examples of Alcock's material, kindly sent to me by the Indian

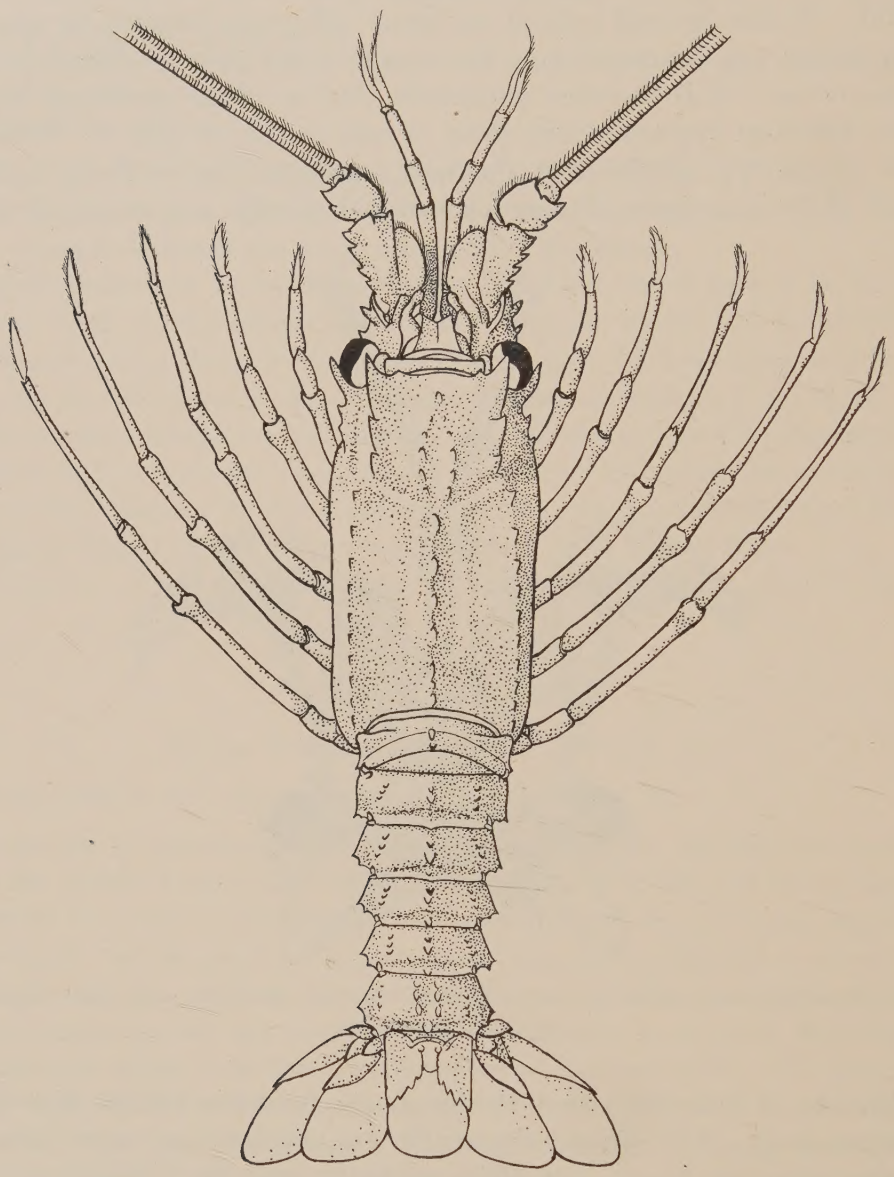


Text-fig. 3.—*Puerulus sewelli*, sp. nov. Ventral view of epistome and basal segments of antennal peduncles.

Museum, Calcutta, it was found that the specimens from the Indian Museum and the examples taken by the John Murray Expedition are identical, and agree very well with the description given by Alcock, but differ markedly from the " Challenger " specimen and from de Man's description. De Man's examples are undoubtedly identical with Spence Bate's species, and the fact that Alcock did not publish any figures of his examples may perhaps account for de Man's failure to differentiate between these and Spence Bate's species.

A new species has been established for Alcock's and the present examples, and I have dedicated it to Lieut.-Col. R. B. S. Sewell. Before proceeding to describe this species, attention may be drawn to a wrong statement in Alcock's description ; Alcock described the carapace as being " half a telson shorter than the abdomen ", and he (*loc. cit.*, p. 186) gives the measurements of a specimen as carapace 70 mm. and abdomen 99 mm.,

so that if Alcock's statement regarding the length of the carapace were correct, the telson should measure about 40 mm. Dr. B. N. Chopra, of the Zoological Survey of India, at the request of Col. Sewell, very kindly measured some of the specimens in the Indian Museum of Alcock's material and he gives the measurements of the specimen that



TEXT-FIG. 4.—*Puerulus sewelli.* Dorsal view, natural size, male.

is specially referred to by Alcock as carapace 70 mm., abdomen without telson 91 mm. and telson 26 mm. From this he presumes that the length of the abdomen, including the telson, given by Alcock must have been measured without straightening it. Alcock's statement should therefore read, " carapace a telson length shorter than the abdomen ".

The lateral margins of the carapace are cut into three teeth, which decrease in posterior succession, in front of the cervical groove and are serrated behind it. The posterior tooth is not far in advance of the cervical groove. On the inner side of the

large supra-orbital tooth there are two small teeth or only a single one that may possess a double head. De Man (1916, p. 37), regarding *Puerulus angulatus* (Spence Bate), writes: "In the 'Challenger' type no teeth did occur between the supra-orbital teeth on the front margin and Col. Alcock does not describe them." These teeth were, however, found to be present in the "Challenger" type of *Puerulus angulatus* (Spence Bate), and also in the two specimens of *Puerulus sewelli* from the Indian Museum. The infra-orbital spine is large, and has below and anterior to it a prominence which is half as long as the spine, and is cut into two teeth, and behind it two other teeth. On the gastric region are two anteriorly convergent, longitudinal rows of eroded spines or elongated tubercles. Behind the cervical groove is a longitudinal carina bearing a row of 7–10 eroded teeth or elongated tubercles, which are of unequal size, and some of which may be double. Usually the last two or three of these are smaller than those anterior to them. The whole surface of the carapace is studded with miliary tubercles, which, on the side walls, are arranged in regular series. The pre-cervical region of the carapace is much shorter than the post-cervical. The transverse part of the cervical groove is very narrow, and from its lateral ends there extend backwards two very shallow grooves, marked by the absence of

Text-fig. 5.—Lateral view of 3–4 abdominal segments of *Puerulus sewelli*.

miliary tubercles. The shape of the region of the carapace enclosed between the cervical groove and these two last mentioned grooves is very characteristic of the species.

The abdominal terga are carinated, the carina of the 6th segment being double. The 2nd–5th terga are transversely grooved near the posterior edge. The carina of the 1st tergum carries a large anterior spine and a smaller posterior one. The carinæ of the 2nd–5th terga each carry two spines anterior to the transverse groove and one posterior to it. Each tergum, from the 2nd to 5th, has at either pleural end a batch of vesicular tubercles in addition to a few small tubercles on either side of the carina. The pleura of the 2nd–5th segments are traversed obliquely by a row of tubercles, and terminate in a pair of teeth which are large in the female and small in the male. The pleuron of the 6th somite ends in a single tooth. The last six thoracic sterna each carry a median tubercle, and the last five have one or two teeth on their raised lateral margins. The 1st abdominal sternum has a transverse row of four spines. The 2nd–5th have each a pair of median spines and the 6th has two transverse rows of spines. These spines are very distinct in the males and young females, but in adult females they almost disappear except on the 1st sternum.

The antennular peduncle is more than half as long as the carapace and the basal segment is longer than the 2nd and 3rd joints together. The antennal peduncle is spinose on its outer margin in adult specimens. In a small specimen from the Indian

Museum it is spinose on both outer and inner margins. In adult specimens the outer margin of the penultimate segment carries four teeth and that of the terminal segment one to three teeth. There is a strong spine at the distal end of the inner margin of the penultimate segment and two very reduced ones on the inner margin of the terminal segment. The antennal flagellum is described by Alcock as being more than twice the length of the body; in none of the specimens from the John Murray Expedition is it complete. The external maxillipeds reach the middle of the 2nd segment of the antennal peduncle and to just beyond the proximal end of the basal segment of the antennular peduncle; its exopodite reaches the middle of the carpus. The proximal halves of the merus and ischium are very strongly serrated on their edges.

In the male the thoracic legs increase in length from the 1st pair, which is about seven-eighths the length of the carapace, to the last pair, which is less than twice as long as the carapace (*vide* the measurements given in the table below). The 1st pair of legs reaches the end of the penultimate joint of the antennal peduncle; the 2nd reaches the end of the terminal segment of the antennal peduncle; the 3rd reaches by half the length of the dactylus beyond the 2nd pair and to the distal end of the 2nd segment of the antennal peduncle; the 4th pair reaches as far as the 3rd and so does the 5th pair. In the female the thoracic legs increase in length up to the 4th pair, and the 5th, which are chelate, are as long as the 4th. The 1st pair of legs reaches the end of the penultimate joint of the antennal peduncle; the 2nd pair reaches the end of the terminal joint of the antennal peduncle; the 3rd pair reaches almost as far as the 2nd, the 4th pair just fail to reaches as far as the 3rd and the 5th reaches the middle of the dactylus of the 4th.

This species differs from *Puerulus angulatus* (Spence Bate) in the following points:

(1) The carapace is much longer in proportion to the abdomen, being almost equal to it without the telson, whereas in *P. angulatus* (Spence Bate) the abdomen is much longer than the carapace (compare the figures given in the table below).

(2) The pre-cervical region of the carapace is much shorter than the post-cervical region, whereas in *P. angulatus* (Spence Bate) the two regions are almost equal. De Man did not give measurements for the two regions in question, but his figure clearly shows that they are almost equal.

(3) The transverse part of the cervical region is very narrow, whereas in *P. angulatus* (Spence Bate) it is broad; the region enclosed between the transverse part of the cervical groove and the two posterior grooves, which extend backward from its lateral ends, differs in the two species and its shape is very characteristic (compare de Man's figure in 1916, pl. xi, fig. 5 of *P. angulatus* with fig. 4).

(4) The 1st pair of legs is only equal to seven-eighths the length of the carapace, the last pair is less than twice the length of the carapace and the last three pairs reach to the same point, whereas in *P. angulatus* the 1st pair are longer than the carapace, the 5th pair in the male is more than twice as long as the carapace, and the last three pairs of legs do not reach to the same point (compare the figures in the table).

(5) The propodus of the 5th pair of legs in the female is more than thirteen times as long as the dactylus, while in *P. angulatus* it is only seven times as long.

(6) The telson is shorter in the present species than in *P. angulatus* (compare the figures in the table on p. 133).

Distribution.—Gulf of Manaar and the Arabian Sea, 264–1327 m. (Alcock).

	Puerulus sewelli sp. nov.										*Puerulus angulatus* (Spence Bate).						
Sex.	Total length.	Carapace.	Pre- and post-cervical regions of carapace.	Abdomen without telson.	Telson.	1st leg.	2nd leg.	3rd leg.	4th leg.	5th leg.	Sex.	Total length.	Carapace.	Abdomen without telson.	Telson.	1st leg.	5th leg.
*♂	161	70	29 + 41	65	26	55	..	..	89	94							
♂	145	66	25 + 41	57	22	55	71	81	91	101	♂	145	53	65	27	60	115
♂	134	59	24 + 35	54	21	50	67	77	87	94	♂	134	49	60	25	..	..
♂	133	58	23 + 35	53	22	49	65	79	90	99	♂	133	46	62	25	..	..
♂	122	51	20 + 35	50	21	44	60	73	86	94	♂	123	43	53	23	..	..
♂	116	50	21 + 29	46	20	45	60	72	85	92	♂	116	40	53	23	..	..
♂	112	47	17 + 30	45	20	40	53	..	75	82	♂	110	38	51	21	..	..
♂	50	20	8 + 12	20	10	..	..	..	..	..	♂	42·5†	16·5	18	8	..	..
*♀	187	82·5	35 + 47·5	76	28·5	65	84·5	97	110	106·5	♀	175	60	82	33	66	110
♀	169	74	31 + 43	69	26	61	75	89	99	98	♀	169	56	81	32	..	..
‡♀	166	71	29 + 42	69	26	57	75	86	99	98	♀	164	56	76	32	..	..
♀	166	69	28 + 41	70	27	56	75	..	98	100	♀	164	56	76	32	..	..
♀	157	65	26 + 39	66	26	55	70	84	99	98	♀	155	53	72	30	..	..
♀	135	54	21 + 33	58	23	45	57	70	82	85	♀	134	46	61	27	..	..
♀	123	50	20 + 30	52	21	41	..	..	77	80	♀	122	42	56	24	..	..

(All measurements are in mm.)

* Specimens in the Indian Museum measured by Dr. Chopra ; the male is the specimen specially referred to by Alcock.

† Type-specimen of *Puerulus angulatus* (Spence Bate) in the British Museum.

‡ Specimen in the British Museum received from the Indian Museum.

? *Puerulus carinatus* Borradaile. (Text-figs. 6 and 7.)

? *Puerulus carinatus*, Borradaile, 1910, p. 261, pl. xvi, fig. 5.

Occurrence.—Sta. 105, Zanzibar area, depth 238–293 m. ; 1 female.

Descriptive Notes.—It is with some doubt that this example is referred to this species. The specimen undoubtedly represents a species other than *P. sewelli* sp. nov. and *P. angulatus* (Spence Bate). The type of *Puerulus carinatus* Borradaile no longer exists, and Borradaile's description of the species, in the light of our present knowledge of the specific characters of both *P. sewelli* and *P. angulatus*, does not help in determining the exact systematic position of the species among its congeners. Borradaile does not give any measurements of the different regions of the body. It is thus only from comparison with Borradaile's figure that this specimen is referred to *P. carinatus*.

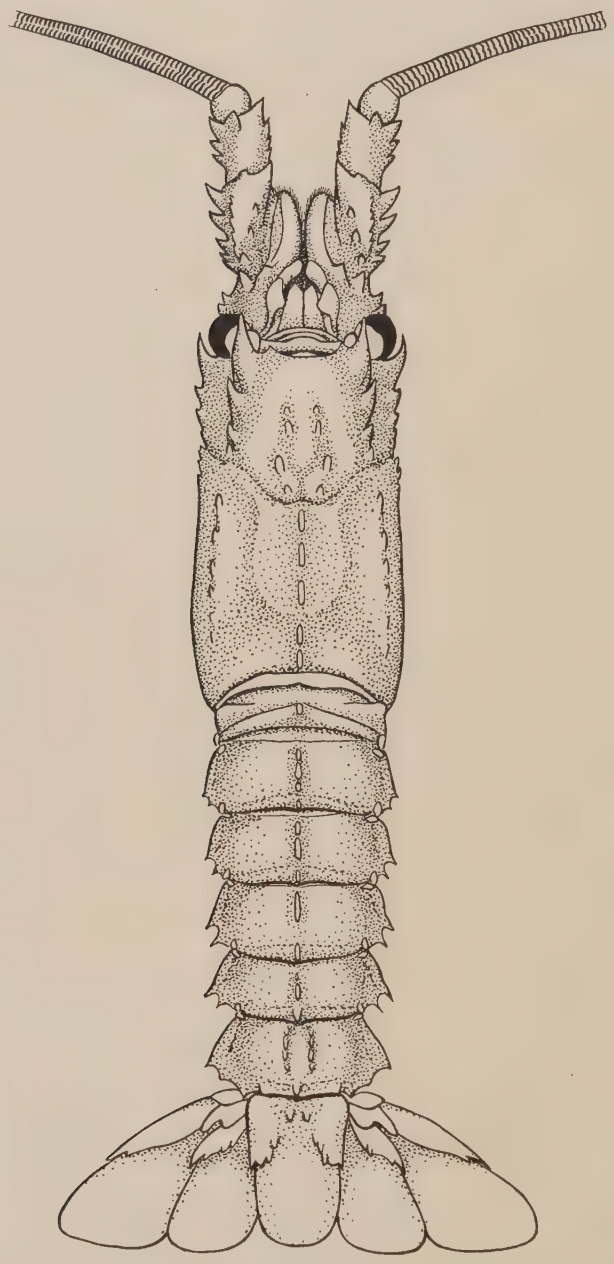
The specimen is intermediate in its measurements between *P. sewelli* and *P. angulatus*.

Total length.	Carapace.	Pre- and post-cervical regions of the carapace.	Abdomen without telson.	Telson.	1st leg.	2nd leg.	3rd leg.	4th leg.	5th leg.
148	56	25 + 31	69	26	48	64	..	99	96

(All measurements are in mm.)

The specimen differs from *P. sewelli* as follows :

(1) The part of the stridulating organ on the 2nd joint of the antennal peduncle is more developed than in *P. sewelli*. When the two 2nd segments of the antennal peduncle of either side are brought into contact with each other along their



TEXT-FIG. 6.—*Puerulus carinatus* Borradaile. Dorsal view, natural size.

inner edges, the two parts of the stridulating organs also touch, while in *P. sewelli* they do not.

(2) The transverse part of the cervical groove is much broader than in *P. sewelli* and the part of the carapace posterior to it is of a different shape.

(3) The denticles of the median carina of the carapace behind the cervical groove are fewer in number (only five) and more elongated than in *P. sewelli*, and

the denticles on the lateral edges of the carapace are also fewer in number (only about seven) and are more developed.

(4) There are three teeth behind the large supra-orbital spine and in front of the cervical groove instead of two in *P. sewelli*.

(5) The denticles on the abdominal pleura and the pleural parts of the terga are obsolete and much less developed than in *P. sewelli*.

(6) The two teeth in which the pleura of the 2nd–5th abdominal segments terminate are of a different shape (compare Text-figs. 5 and 7).

(7) The antennular flagellum shows red and uncoloured alternating bands, while that of *P. sewelli*, is of a uniform tint. These bands could not have existed in *P. sewelli*, and have disappeared through the action of the spirit in which the animal has been preserved, as all the material has been in spirit for the same period and no trace of alternating bands exists in the abundant material of *P. sewelli*.

TEXT-FIG. 7.—? *Puerulus carinatus* Borradaile. Lateral view of 3rd and 4th abdominal segments.

From *P. angulatus* (Spence Bate) this specimen differs mainly in the following :

(1) The relative length measurements of the abdomen and carapace, the pre- and post-cervical regions of the latter and of the legs.

(2) The shape and number of denticles on the median carina of the carapace and its lateral edges.

(3) The propodus of the 5th legs (female) is about twelve times the length of the dactylus, whereas in *P. angulatus* it is only seven times as long.

Borradaile's figure shows : (1) A well-developed stridulating organ on the 2nd joint of the antennal peduncle ; (2) elongate tubercles on the median carina of the carapace and on its lateral edges ; (3) a broad transverse part of the cervical groove. In these respects the specimen resembles Borradaile's figure. The only difference between Borradaile's figure and the present specimen is that in the latter there are three teeth behind the large supra-orbital tooth, whereas the figure shows only two ; but in the figure the 2nd of these teeth is far removed from the cervical groove and it is possible that a very small 3rd tooth may have been overlooked or else was obsolete, as might be expected in such a large specimen (190 mm.).

DISTRIBUTION.—Saya de Malha and Zanzibar area.

LITERATURE.

ALCOCK, A. 1901. A Descriptive Catalogue of the Indian Deep-Sea Decapoda (Macrura and Anomala) in the Indian Museum, Calcutta. 286 pp.

—— and others. 1892–1908. Illustrations of the Zoology of the " Investigator ", Crustacea parts i–xii. Calcutta.

Balss, H. 1925. Macrura. 1. *Palinura, Astacura* und *Thalassinidea* in Wiss. Ergebn. Deutschen Tiefsee-Exped. XX, heft 4–5, pp. 189–216, 2 pls., 16 text-figs.

Boone, L. 1935. Scientific Results of the World Cruise of the Yacht "Alva" 1931: *Crustacea* and *Echinodermata*. Bull. Vanderbilt Mar. Mus. Huntington, N.Y. 6, pp. 1–264, 96 pls., 13 text-figs.

Borradaile, L. 1910. *Penæidea, Stenopidea* and *Reptantia* from the Western Indian Ocean. Trans. Linn. Soc., London, ser. 2, XIII, pp. 257–264, pl. xvi.

Bouvier, E. L. 1917. Crustacés Decapodes (*Macroures marcheurs*): Résultats des Campagnes Scientifiques . . . Rés. Camp. Sci. Monaco, L, 140 pp., 11 pls.

Calman, W. T. 1909. The Genus *Puerulus* Ortmann and the Post-larval Development of the Spiny Lobsters (*Palinuridæ*). Ann. Mag. Nat. Hist., London, ser. 8, III, pp. 441–446.

—— 1925. On Macrurous Decapod Crustacea Collected in South African Waters by S.S. "Pickle". With a Note on Specimens of the Genus *Sergestes* by H. J. Hansen. Rep. Fish. Mar. Biol. Survey Cape Town, IV, No. 3, pp. 1–26, 4 pls.

Desmarest, A. G. 1825. Consideration Générales sur la Classe Crustacés. Paris.

Faxon, W. 1895. The Stalked-eyed Crustacea of the "Albatross". Mem. Mus. Comp. Zool. Harvard, XVIII, 292 pp., pls. A-K and 1–56. Cambridge, Mass.

—— 1896. Supplementary Notes on the Crustacea of the "Blake". Bull. Mus. Comp. Zool. Harvard, XXX, pp. Cambridge, Mass.

Gruvel, A. 1911. Contribution à l'Étude Générale Systématique et Économique des Palinuridæ, Paris. Ann. de l'Inst. Océanogr. III, fasc. 4, 56 pp., 6 pls. Paris.

Henderson, J. R. 1893. A Contribution to Indian Carcinology. Trans. Linn. Soc., London (2), V, pt. 10, pp. 325–458.

Kemp, S., and Sewell, R. B. S. 1912. Notes on Decapoda in the Indian Museum: IV. Rec. Indian Museum, Calcutta, VII, pp. 15–32, 1 pl.

Leach, W. E. 1815. Zoological Miscellany, Vol. II.

de Man, J. G. 1916. The Decapoda of the "Siboga" Expedition. Part III. *Eryonidea*, etc. Mon. 39 a^2 der Ergebnisse der "Siboga", LXXVI, pp. 1–122, 4 pls. Leyden.

Miers, E. 1881. On a Collection of Crustacea from Goree Island, Senegambia. Ann. Mag. Nat. Hist., ser. 5, VIII, pp. 204–220, 259–377, pls. xiii–xvi. London.

Milne-Edwards. 1834, 1837, 1840. Histoire Naturelle des Crustacés. Roret's Suite à Buffon, I–III, 42 pls. Paris.

Nobili. 1906. Faune Carcinologique de la Mer Rouge. Décapodes et Stomatopodes. Ann. Sci. Nat. (Zool.), Paris, IV, pp. 1–347, pls. i–xi.

Ortmann, A. E. 1892. Die Decapoden Krebse des Strassburger Museums. No. III. Die Abtheilungen der Reptantia Boas: *Homaridæ, Loricata* und *Thalassinidea*. Zool. Jahr. Syst. V, pp. 1–57.

—— 1901. Decapoden. Bronn's Klassen und Ordnungen des Tierreichs. Leipzig.

Selbie, C. M. 1914. The Decapoda Reptantia of the Coasts of Ireland. Fish. Ireland Sci. Invest. 1914, I, 116 pp., 15 pls. Dublin.

Stebbing, T. R. R. 1893. A History of Crustacea. Recent *Malacostraca*. Internat. Scient. Series. London.

—— 1902. South African Crustacea, Part 2. Marine Invest. South Africa, Cape Town, 92 pp., pls. v–xvi.

—— 1910. General Catalogue of South African Crustacea, Cape Town. Ann. S. Afr. Mus. VI, pt. iv, pp. 281–593, pls. xv–xxii.

Stephensen, K. 1923. Decapoda Macrura excl. *Sergestidæ*. Report on the Danish Oceanographical Expeditions 1908–1910 to the Mediterranean and the Adjacent Seas, II, Biology, pt. D3, pp. 1–85, 27 figs. and 8 charts. Copenhagen.

APPENDIX I

ON LUMINOSITY IN PENÆIDÆ, WITH A DESCRIPTION OF THE PHOTOPHORES OF *HYMENOPENÆUS DEBILIS*

By M. RAMADAN, Ph.D.(Cantab.)

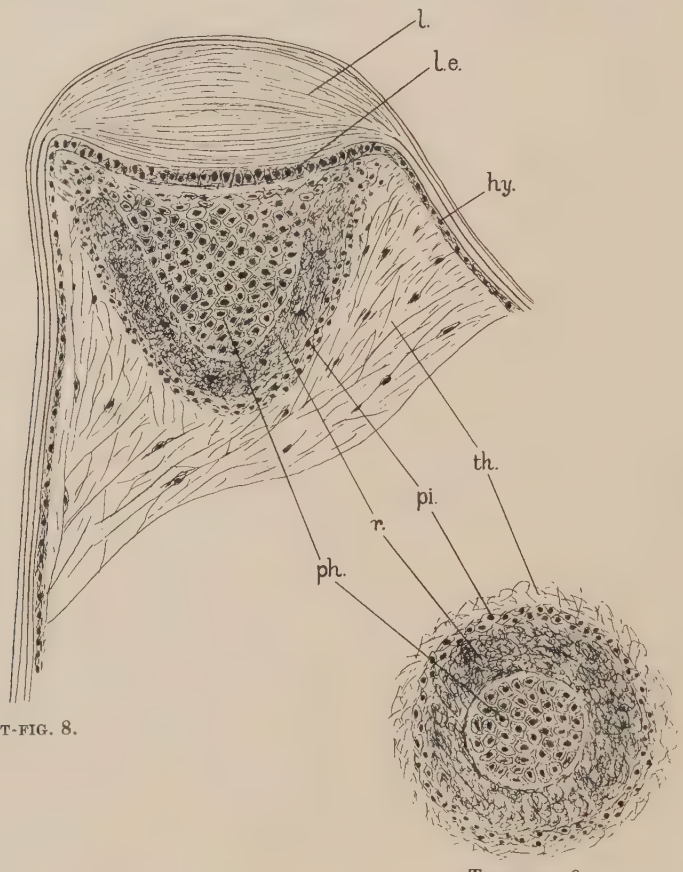
In the family Penæidæ only two species, *Hymenopenæus debilis* and *Plesiopenæus coruscans* (Wood-Mason), are known to possess the property of producing light. Burkenroad (1936, p. 118) suggests that other species of *Hymenopenæus* with large eyes may have photophores. Kemp also (1910*a*, p. 15) suggests that the blue pigment in *Gennadas elegans* may prove to be associated with luminous function. The two species, however, produce light differently. In *P. coruscans* the excretions from or from near the antennal glands have been noticed by Alcock (1902, pp. 134–135) to be brilliantly phosphorescent; the exact origin of such luminous fluids is not known, but Dahlgren (1916, pp. 829–832) concludes that the chemical substance responsible for the luminosity is secreted by some of the integumentary glands. *H. debilis*, on the other hand, possesses fairly well-developed photophores. It may be mentioned that among *Crustacea* the occurrence of compound photophores is limited to the *Eucarida*, and that both types of production of light (*i. e.* the possession of photophores and the ejection of luminous fluid) are not known to occur together except in one species of *Systellaspis* (Harvey, 1931, p. 71). The presence in *H. debilis* of organs which must undoubtedly be regarded as photophores was recently discovered by Burkenroad (1936, p. 112), who, having no time himself for a detailed examination of the organs, has very kindly sent me a few specimens for study. The following is an account of the result of my examination.

The photophores are relatively large, six in number, conical in shape and arranged as follows: (1) A pair on the posterior margin of the sternum of the 7th thoracic segment, just median to the coxæ of the 4th thoracic legs; (2) a pair between the 2nd pleopods; and (3) two unpaired organs placed respectively between the bases of the 4th and 5th pairs of pleopods, and directed posteriorly. In the specimens examined by me the paired organs are larger than the single ones, and it seems that there is a gradual decrease in size from before backwards. The largest organ, including the lens, measures 0·35 mm. by 0·30 mm.

Histological examination of the alcoholic material shows that the photophore is composed of the following parts: (1) The lens, (2) the lens epithelium, (3) the photic cells, (4) the reflector, (5) the pigment mantle, (6) connective-tissue theca, and (7) nerves.

The Lens.—This is a strongly thickened part of the general cuticula of the body and contains layers directly continuous with the three layers of the latter. On the outermost side there is a delicate investing membrane, which is of the same thickness as that investing the general cuticula. Below this is the lens proper, which is bi-convex. Both Hansen (1903) and Kemp (1910) describe the lens of *Sergestes challengeri* as made of two

parts, an outer bi-convex and an inner concavo-convex portion. Terao (1917) describes the lens of the photophore of *Sergestes lucens* (the species of *Sergestes*, referred to by Terao as *Sergestes prehensilis*, of the photophores of which he gives a detailed description, is not *S. prehensilis*, but *S. lucens* [see Gordon, 1935, p. 308]) as also made of two parts, an outer *concavo-convex* and an inner bi-convex part. In *Hymenopenæus debilis*, however, the lens does not show any differentiation into parts ; it is a simple chitinous structure showing the usual striations. The two main layers of the general cuticula simply merge into it without differentiation into parts.



Text-fig. 8.

Text-fig. 9.

Text-fig. 8.—Longitudinal section of the photophore of *Hymenopenæus debilis*.
Text-fig. 9.—Transverse section of the photophore of *Hymenopenæus debilis*. *l.*, lens ; *l.e.*, lens epithelium ; *hy.*, hypodermis ; *ph.*, photic cells ; *r.*, reflector ; *pi.*, pigment mantle ; *th.*, theca.

The Lens Epithelium.—This is continuous with the general hypodermal layer, and only differs in that the cells are larger than the normal cells of the hypodermis. In some organs the nuclei of the lens epithelium are pressed against the lens, while in others they are placed in the middle of the cells and in this case the cells are higher than broad. It may be that the cells in such cases represent an active stage and are going to divide, giving rise to photogenous cells. This will be referred to below under the pigment mantle. It might be mentioned here that Terao has noticed in the lens-forming epithelium of *Sergestes lucens* karyokinetic figures, the spindle axis of which is directed vertically to the epithelial layer. The presence of a distinct lens epithelium is emphasized here because in *Sergestes challengeri* (Kemp, 1910*b*) no such layer exists between the lens and the photic cells.

The Photic Cells.—These form a compact pyriform mass. The cells are large and irregular in shape, and their nuclei are fairly large.

The Reflector.—This is of a conical shape and surrounds the photogenous mass, from which, however, it is free. There is no basement membrane, such as that described by Terao, which separates the photogenous mass from the reflector. The reflector is fairly thick and consists of a dense network of protoplasm, which contains a very small number of nuclei scattered in an irregular shape.

The Pigment Mantle.—This consists of a layer of connective tissue 3–4 cells thick. It completely surrounds the reflector and anteriorly enters the space between the lens epithelium and the reflector. Although the alcoholic material, which alone was available to me, contained no pigment, this connective-tissue layer may, from a comparison with the homologous structure in the photophore of *Sergestes lucens*, be assumed to be the pigment mantle. In this latter species a band of connective tissue, external to the reflector, is described by Terao (1917, p. 314, fig. 3) as the pigment mantle. In *Sergestes challengeri*, also, on the outer side of the reflector there is a connective layer which is supposed by Kemp to be the pigment carrier. As to the colour of the photophore in *Hymenopenæus debilis*, Burkenroad (1936, p. 112) writes that in fresh, though dead material the photophores are seen through the transparent cuticle as brilliant scarlet conical bodies with a glistening white base below abutting against the cuticular lens. In this respect (*i. e.* the colour of the photophore) *Hymenopenæus debilis* resembles *Chlorotocoides spinicauda* (de Man) and *Thalassocaris lucida* (Dana), in which the colour is red in the upper part, with a glistening white base (*vide* Kemp, 1925, p. 277). In some photophores there are between the lens epithelium and the photogenous mass some cells similar to the photic cells, but smaller in size. Running between these cells are some connective-tissue fibres, which seem to be derived from the connective tissue of the pigment mantle. These cells are most probably newly formed photic cells. It is difficult to state definitely from the sections obtained whether they owe their origin to the lens epithelium or to the pigment mantle. The first supposition finds support from the fact that Terao, as stated above, has found karyokinetic figures in the lens epithelium of the photophores of *Sergestes lucens*.

The Theca.—This is a band of loose connective tissue surrounding the so-called pigment mantle. The fibres run nearly parallel.

The Nerves.—Both Kemp (1910) in *Sergestes challengeri* and Terao (1917) in *Sergestes lucens* have failed to discover the exact entrance of the nerve into the photophore. Kemp writes that it is not improbable that the nerve-strand runs round the edges of the reflector inwards; in much the same way as has been demonstrated by Chun in the photophore of the Euphausiacea. On the other hand, Terao states that some slender fibres were observed penetrating into the reflector from the internal convex mass and that they were probably of nervous nature. In the photophore of *Hymenopenæus debilis* the entrance of the nerve strand could not be followed right into the inside of the photophore ; but it has been followed to such an extent as definitely to exclude the idea of the entrance of the nerve through the reflector. In a series of longitudinal sections of a photophore from the 2nd abdominal segment the nervous strand could be traced until it entered the theca, and it was then found to run parallel and close to the pigment mantle on the outer side of the photophore ; it is thus very probable that the entrance of the nerve into the photogenous mass is of the same type as in the Euphausiacea, as suggested by Kemp.

The photophores of *Hymenopenæus debilis* differ from those of *Sergestes lucens* and *S. challengeri* in that they are (i) larger in size ; (ii) fewer in number, only six being present * ; (iii) of a different shape, being conical rather than spherical ; (iv) differently distributed ; (v) of a different colour ; and (vi) of a different structure. The internal structure differs considerably from that of the photophores in *Sergestes*, for they possess no basement membrane, such as that described by Terao, separating the photogenous mass from the reflector ; but the most important difference is that in *Sergestes* the photogenous mass consists of a single layer of cells, whereas here it is composed of a pyriform mass of cells.

LITERATURE.

Alcock, A. 1902. A Naturalist in Indian Seas. Calcutta.

Burkenroad, M. D. 1936. The Aristæinæ, Solenocerinæ and Pelagic Penæinæ of the Bingham Oceanographic Collection. Bull. Bingham Oceanogr. Coll. II, 151 pp., 71 text-figs.

Dahlgren, U. 1916. The Production of Light by Animals ; the Luminous Crustaceans. Journ. Franklin Inst. CLXXXI, p. 805.

Gordon, I. 1935. On New and Imperfectly Known Species of Crustacea Macrura. Journ. Linn. Soc., London, Zool. XXXIV, pp. 307–351, 27 text-figs.

Hansen, H. J. 1903. On the Crustaceans of the Genera *Petalidium* and *Sergestes* from the " Challenger ", with an Account of the Luminous Organs in *Sergestes challengeri*, n. sp. Proc. Zool. Soc., London, I, pp. 52–79, pls. xi and xii.

Harvey, E. N. 1931. Chemical Aspects of the Luminescence of Deep Sea Shrimp. Zoologica (Sci. Contr. New York Zool. Soc.), XII, p. 71.

Kemp, S. 1910*a*. The Decapoda Natantia of the Coast of Ireland. Dublin Fish. Ireland Sci. Invest., 1908 (1910), No. 1, 190 pp., 23 pls.

—— 1910*b*. Notes on the Photophores of Decapod Crustacea. Proc. Zool. Soc., London, II, pp. 639–651, pls. lii–liv.

—— 1925. Notes on Crustacea Decapoda in the Indian Museum. XVII. On Various Caridea. Rec. Ind. Mus., Calcutta, XXVII, pp. 249–343, 23 figs.

Terao, A. 1917. Notes on the Photophores of *Sergestes prehensilis*, Bate. Annot. Zool. Japonen. IX, pp. 299–316, figs.

---

* Gordon (1935, p. 308) states that in *Sergestes gloriosus*, Kemp, who in the course of his work on board the " Discovery " made a careful study of the photophores, found that the total number present varied with age and size, and Kemp (1910, p. 61) states that in *Acanthephyra debilis* A. M.-Edw., " the larval form possesses only twelve photophores (six pairs), while no less than one hundred and forty-seven are to be found in the largest specimens ". In the present species photophores to the same number, six, are present in all post-larval stages.

APPENDIX II

ON THE STRUCTURE OF THE OCULAR PEDUNCLES IN DEEP AND SHALLOW-WATER FORMS OF THE PENÆIDÆ*

By M. RAMADAN, Ph.D.(Cantab.)

The following study of the ocular peduncles of the Penæidæ was carried out with the object of discovering to what extent, if at all, the several groups of the family differ from one another in respect of the general structure of these organs, and whether any of the observed differences can be correlated with differences of habitat.

In the Aristæinæ the ocular peduncle is simple and the cornea is, as a rule, hemispherical; whereas in the Penæinæ and Eusicyoninæ the peduncle is complex and the cornea is always reniform. The fact that the Penæinæ and Eusicyoninæ are littoral forms and the Aristæinæ are deep-sea forms suggests that these differences, as roughly outlined above, may be due to adaptation to their different habitats; the answer to this question, namely, whether such differences are really due to habitat-adaptation, must be sought in the members of the Solenocerinæ, some members of which are truly abyssal, while others live in comparatively shallow waters, inhabited also by some members of the Penæinæ.

Among the Penæidæ two types of ocular peduncle are present, namely, a simple type and a complex one.

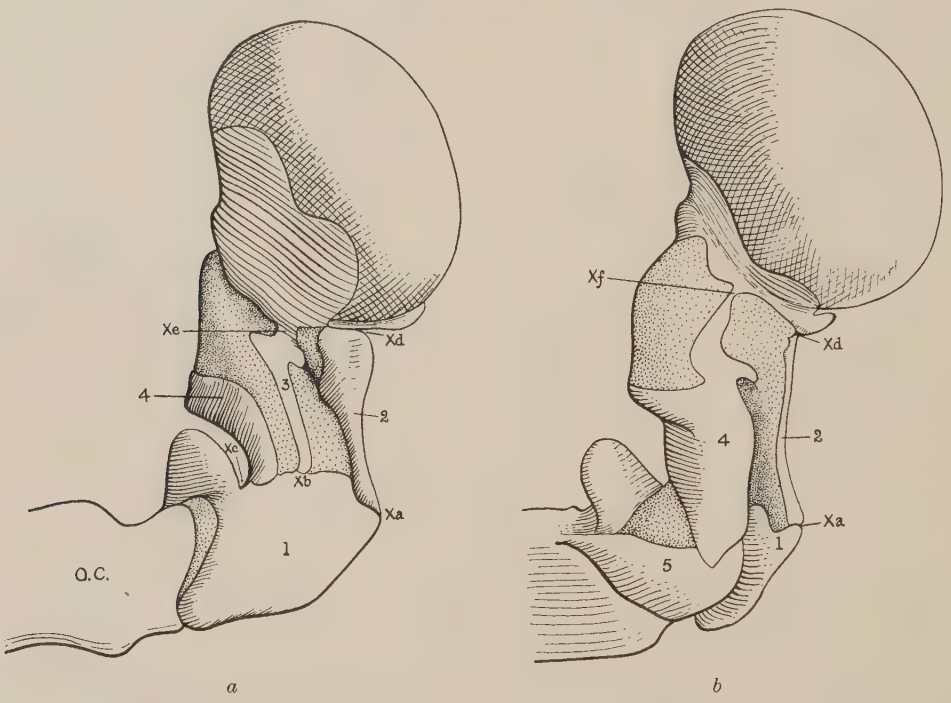
Simple Peduncle.—In this type the peduncle is very simple and the condition found in *Plesiopenæus edwardisianus* may be taken as representative (Text-fig. 12, *c*). The cornea is hemispherical and the peduncle is composed of two segments, the 1st or proximal being much smaller than the 2nd. The wall of the two segments is of uniform thickness. When the peduncle is moved, the position of the cornea changes with reference to the long axis of the animal.

Complex Peduncle.—In this second type the eye is usually reniform, the inner side of the eye and a portion of the dorsal side being blind (Text-figs. 10, *a* and *b*). If the articulation of the segments of the peduncle were as in the simple type, on the abduction of the peduncle the inner or blind side of the eye would be swung into a position occupying the sector for anterior vision. To avoid this a special peduncular mechanism has been evolved in order to keep the cornea always in the same plane with reference to the long axis of the organism, and thus prevent the inner blind side of the eye from occupying the sector for anterior vision. I give below a description of the peduncle of *Penæus trisulcatus*, a species that possesses this type of mechanism, and show how the mechanism is effective.

In this peduncle (Text-fig. 10) the exact limitation between a first and a second segment

* I wish to express my thanks to Mr. M. D. Burkenroad, of the Peabody Museum, Yale, who suggested to me a study of the habitat adaptations of the Penæinæ. Owing to lack of time the work was confined to a study of the eyes and ocular peduncles.

is not clearly seen. While on the dorsal side one may say that there are two segments, it is almost impossible from the ventral side to tell what belongs to the 1st and what to the 2nd segment; for this reason in the following description no reference will be made to individual segments, but the whole peduncle will be considered as a single unit. The walls of the peduncle are not of uniform thickness; there are a certain number of sclerites, between which the wall is very soft. Besides the sclerites the part which forms the inner blind side of the eye is composed of fairly hard chitin. Sclerite 1 is firmly attached to the ocular somite and is bent on itself posteriorly, the bent part being visible on the ventral side. Sclerite 2 lies on the lateral side of the peduncle, and is attached posteriorly to sclerite 1 and anteriorly to the blind part of the eye. Sclerite 3 is dorsal in position, and is attached posteriorly to sclerite 1 and anteriorly to the eye. Sclerite 4



a *b*

TEXT-FIG. 10.—Ocular peduncle of *Penœus trisulcatus*. *a*, Right eye, dorsal view; *b*, left eye, ventral view.

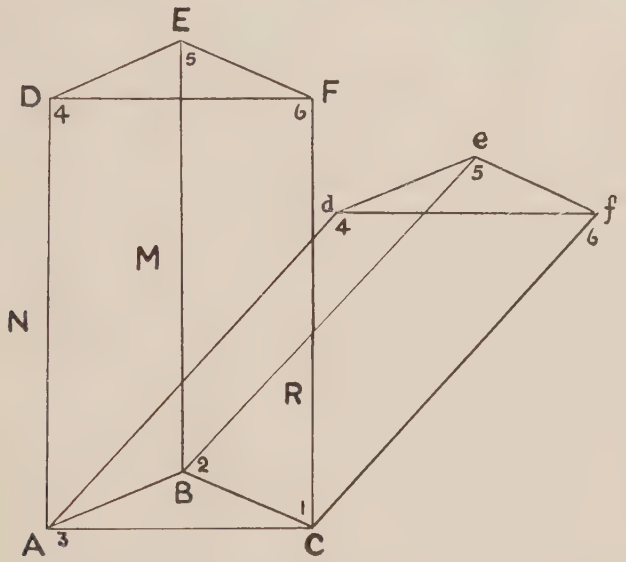
is very broad and occupies part of the inner side of the peduncle and a good part of the ventral side, as well as appearing on the dorsal side also; it is attached to sclerite 1 and, anteriorly, to the eye. Sclerite 5 is ventral and is attached posteriorly to the ocular somite and anteriorly, through a small flexible piece, to sclerite 4. Dorsally on the inner side of sclerite 2 there is a cavity, the walls of which are composed of soft tissue, and ventrally on the inner side of the same sclerite there is a second cavity of the same nature; both cavities, with the movement of the eye, take different shapes. The parts at which the sclerites articulate with each other (marked × in the figures) act as a kind of hinge, which permits movement, but is not extensible.

The mechanical action of the apparatus described in the foregoing paragraph is as follows: Sclerites 2, 3 and 4, supporting the eye on their distal ends, can swing to and from the median line on their articulations in such a manner that the eye retains its relation to the long axis of the body. This is shown in principle in the diagram (Text-fig. 11). Plates ABC and DEF are comparable respectively to sclerite 1 and the sclerite which forms

the blind side of the eye. The lines N, M and R are comparable to sclerites 2, 3 and 4. In whichever direction N, M and R move, plate DEF will remain parallel to plate ABC. Since sclerite 1 is fixed to the ocular somite, the eye thus retains its relation to the latter and to the longitudinal axis of the animal.

THE DISTRIBUTION OF THE TWO TYPES OF PEDUNCLE IN THE PENÆIDÆ.

The simple type of peduncle occurs in the Aristæinæ ; the complex peduncle is found in the Penæinæ, Eusicyoninæ and Solenocerinæ, and in the Penæinæ and Eusicyoninæ is of the type described in *Penæus trisulcatus*. In these two sub-families, with the single exception of the genus *Funchalia*, the eye is reniform and the inner blind area of the eye



TEXT-FIG. 11.—Diagram illustrating the mechanism of the complex peduncle.

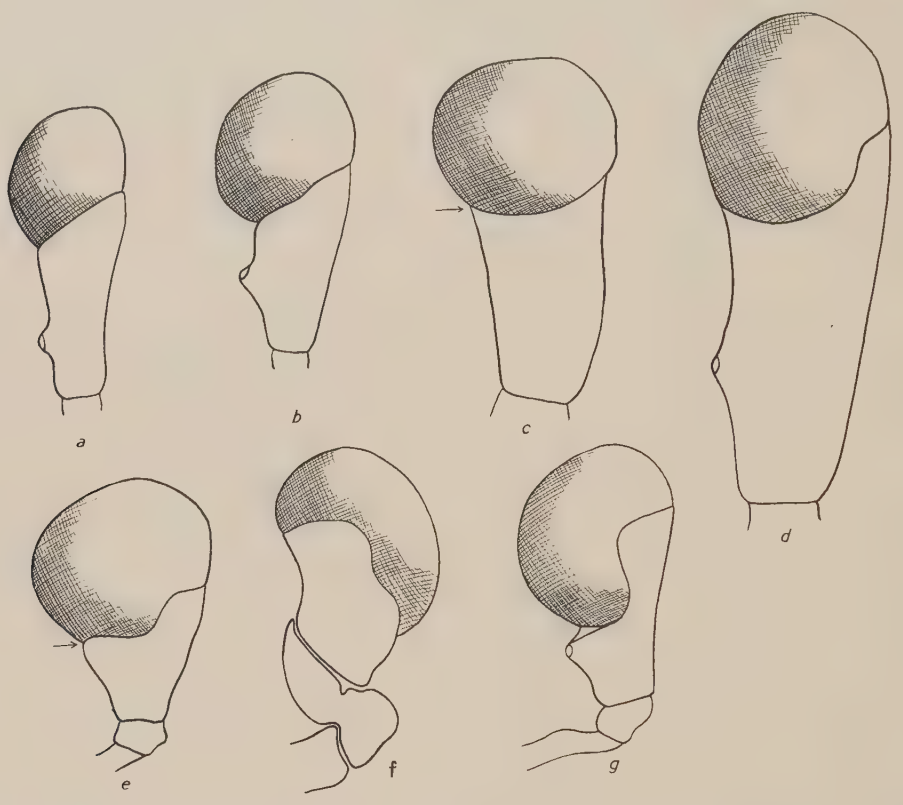
is large. Species of the following genera were examined by me : *Eusicyonia*, *Penæus*, *Funchalia*, *Metapenæus*, *Atyopenæus*, *Parapeneopsis*, *Xiphopenæus*, *Trachypenæus*, *Peneopsis*, *Parapenæus*, *Artemesia* and *Macropetasma*.

The most complex type of peduncle is found in species of *Penæus*. In *Parapenæus fissurus* (Text-fig. 12, *f*) and other species the chitinous structure, which forms the inner blind side of the eye, extends backward, covering the articulations (Xd, Xe and Xf), and sclerite 1 (Text-fig. 10) extends forward, so that, when the eye is in the normal position, the whole mechanism is concealed.

This type of complex peduncle is transitional to the state of affairs which we find in the Solenocerinæ, in which the mechanism is so reduced that the complex peduncle may easily be mistaken for a simple one.

Among the Solenocerinæ there is a steadily progressive development of complexity in the peduncle in the several species as we pass from the depths upwards to the littoral region. In *Solenocera*, a genus which lives at far shallower depths than some species of *Hymenopenæus* and *Haliporus*, we find the highest development of the peduncle in the sub-family. In some species of the genus, *e. g. Solenocera hextii*, the peduncular mechanism

is almost as highly developed as it is in the Penæinæ, while in others, *e. g. S. africanus*, although the mechanism is as developed as it is in any of the species of the genus, there is a backward prolongation of the eye sclerite which recalls the peduncle of *Parapenœus*. In *Hymenopenœus* there are different degrees of development of the peduncle, which can be correlated with the depth of habitat. In all the species of this latter genus the eye sclerite is prolonged backwards. The higest degree of development in the genus is found in *H. mulleri*, a littoral form from 13–80 metres ; here the three sclerites 2, 3 and 4 (Text-fig. 10) are well developed and the character of the peduncle comes near to that of



Text-fig. 12.—Ocular peduncle of (a) *Hepomadus tener ;* (b) *Hemipenœus crassipes ;* (c) *Plesiopenœus edwardisianus ;* (d) *P. armatus ;* (e) *Aristeomorpha foliacea ;* (f) *Parapenœus fissurus ;* (g) *Aristeus alcocki.* The arrow indicates the position of the ocular tubercle.

Parapenœus. In species living at greater depths than that inhabited by *H. mulleri*, namely, in *H. triarthus* and *H. sibogæ* from about 450 metres depth, there is a less developed peduncular mechanism, and in *H. neptunus* and *H. lævis*, two species which live at still greater depths, we find a further degree of simplification in the peduncle. In the latter species the three sclerites 2, 3 and 4 are much shorter and weaker and the eye sclerite is much prolonged backwards. Associated with this prolongation of the eye sclerite there is a backward shifting of the sclerite articulations, Xd, Xe and Xf, from near the eye to the proximal part of the peduncle. In *Haliporus curvirostris*, an abyssal form from 2340 metres depth, the reduction has proceeded to the extreme ; the three sclerites are very feeble and very short, the backward prolongation of the eye sclerite has gone on to a high degree, so that it now gives one an impression of representing segment 2 of the simple peduncle of the Aristæinæ. There is thus but little doubt of the relationship

between the degree of development of the complex ocular peduncle and the depth at which the species lives.

If the complex type of peduncle has arisen from the simple type, as would seem to be most probable, then clearly its development is associated with the possession of a reniform type of eye, and the necessity of preventing the blind side of the eye from being brought into the forward position when the peduncle is swung outwards. Hence a complex peduncle should be associated with a reniform eye and the simple peduncle with a hemispherical one ; and this is actually the case except for three exceptions.

In *Aristeus* (Text-fig. 12, *g*) the peduncle is simple, but the cornea is reniform, when we should expect it to be hemispherical ; in this species, however, the blind side of the eye, contrary to the condition found in the Penæinæ, is on the *outer side* of the eye and thus will not interfere with anterior vision when the peduncle is swung outwards. The second exception is *Hymenopenæus mulleri*, which possesses a hemispherical, instead of a reniform, eye ; but of all the Solenocerinæ examined this species inhabits the shallowest waters, occurring between 80 to as little as 13 m. depth, and it is therefore practically littoral in its habitat, and one would expect the peduncle to be as highly developed as in the Penæinæ. Actually the peduncle is only moderately developed, and hence we get the necessity for the hemispherical type of eye to counter-balance the lower efficiency of the peduncle.

We are thus left with the third instance, the genus *Funchalia*, as the only real exception, and here we are dealing with a form that has a very special habitat, namely, the upper surface layers of the open ocean, and we thus find the maximum degree of efficiency, namely, the combination of a hemispherical type of eye with a highly complex ocular peduncle.

Table of Species Examined, Showing the Type of Peduncle, the Degree of Development, the Shape of Cornea and the Depth at which the Species Lives.

Species.	Type of peduncle.	Degree of development of peduncle.	Depth.	Shape of cornea.
Sub-family Eusicyoninæ :				
Eusicyonia	Complex	++++	Littoral	Reniform
Sub-family Penæinæ :				
All genera except *Funchalia* (*vide supra*, p. 145)	,,	++++	,,	,,
Funchalia	,,	++++	Upper waters of the ocean	Hemispherical
Sub-family Solenocerinæ :				
Solenocera hextii	,,	+++	119–505 m.	Reniform
S. africanus	,,	+++	61 m.	,,
Hymenopenæus mulleri	,,	+++	13–80 m.	Hemispherical
H. triarthus	,,	++	400 m.	Reniform
H. sibogæ	,,	++	450 m.	,,
H. neptunus	,,	+	3109 m.	,,
H. lævis	,,	+	878–1957 m.	,,
Halipoŕus curvirostris	,,	Almost simple	4279 m.	,,
Sub-family Aristæinæ :				
Aristeus alcocki	Simple	..	270–1022 m.	,,
Hemipenæus crassipes	,,	..	500–1737 m.	Hemispherical
Plesiopenæus edwardisianus	,,	..	550–1850 m.	,,
P. armatus	,,	..	750–5400 m.	,,
Aristeomorpha foliacea	,,	..	400–1300 m.	,,
Hepomadus tener	,,	..	2304–3140 m.	,,